Engineering Capability Enhancement with Microfluidics

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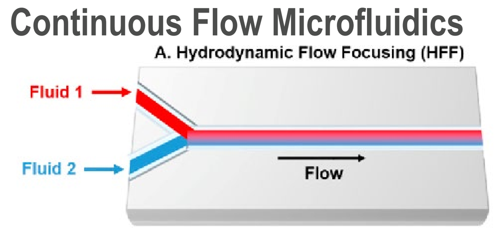
Introduction

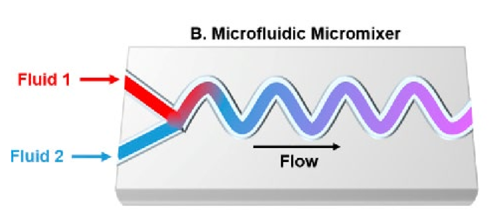
MRIGlobal offers systems engineering expertise to a wide range of customers, aiding in device development, testing, and validation. As point-of-need applications become more common, many of these customers are looking for increased portability and reduced user interactions. This means devices are becoming smaller and more complex, requiring miniaturized structures and innovative systems integration. One key technology that has supported device miniaturization is the integration of microfluidics. This technology has proven critical to the size reduction, weight reduction, and automation of devices, particularly in the area of personal health. With point of care sensing and diagnostics devices seeing a substantial increase during the pandemic, microfluidics expertise is important to the development of next generation devices. As such, the engineering department seeks to expand their microfluidics capabilities to provide more value to customers for device development, improve systems engineering expertise to maintain a competitive edge, and support interdepartmental collaboration with physical and life sciences

Background

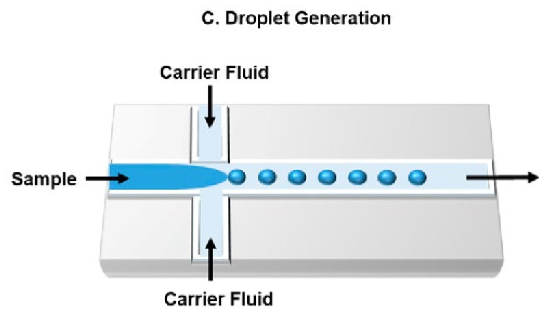
As technology advances, devices have displayed a trend toward miniaturization. To continue this trend, disciplines ranging from chemical synthesis to medical diagnostics have begun to integrate microfluidics. Microfluidics refers to both the technology involved in controlling the flow of fluid in microchannels, as well as the science that studies the behaviors of fluids at the microscale. The three main types of microfluidics are continuous flow, droplet; where the flow is segmented into droplets with different compositions, and digital, where individual droplets are controlled by an electric field.

Continuous Flow Microfluidics

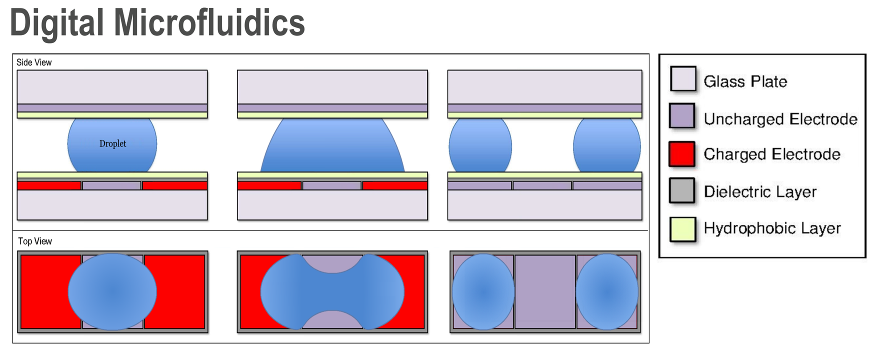




Droplet Microfluidics

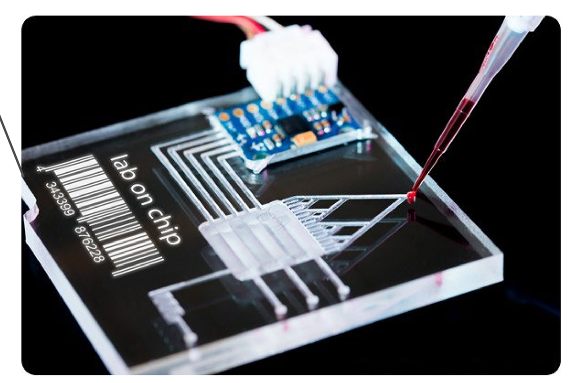


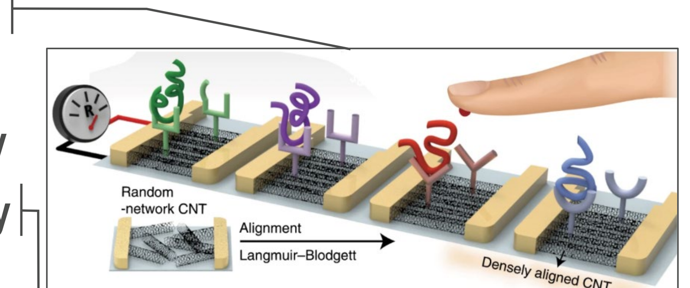
Digital Microfluidics

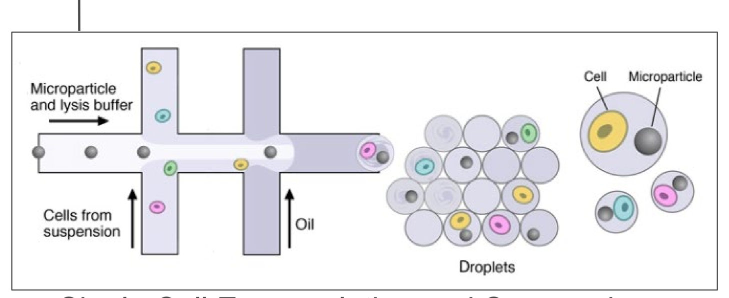


Benefits

- Reduced Cost and Reagents
- Reduced Sized
- Sensor/Device Integration
- Faster Processing
- Reduced User Interaction
- High Throughput
- Multiplexed Sensing
- Ease of Automation
- Increased Portability
- Increased Sensitivity



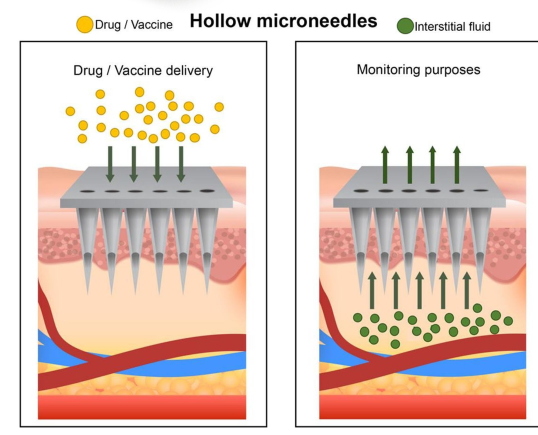




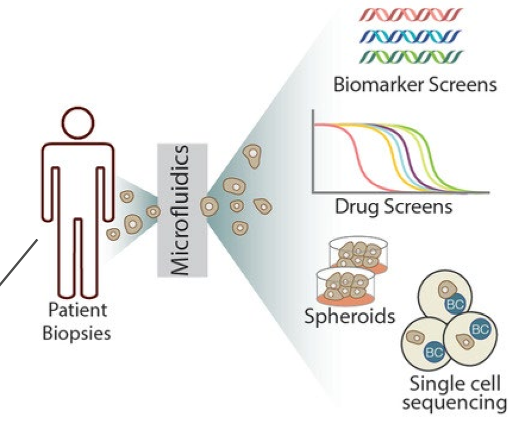
Single Cell Encapsulation and Sequencing

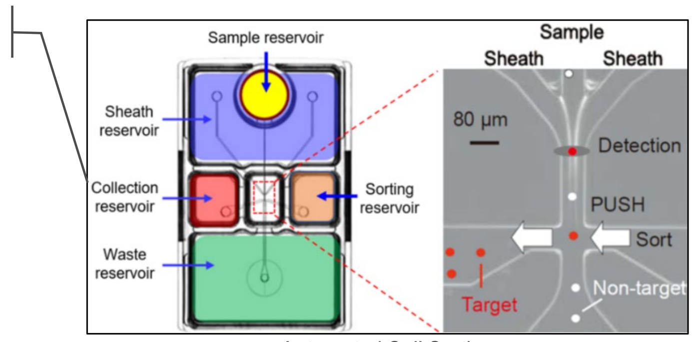
Applications


MinION Sequencer – Oxford Nanopore



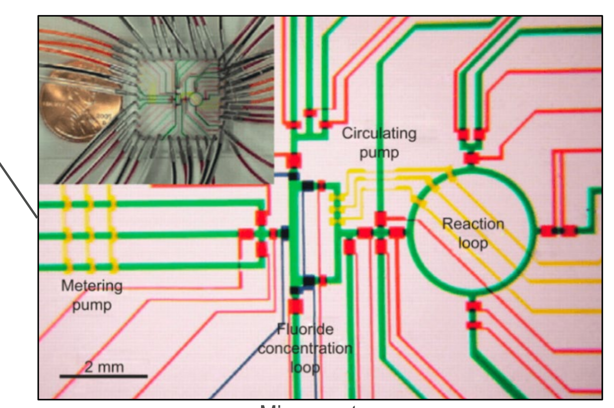
- Sensing and Diagnostics
- Genetic Sequencing
- Synthetic Biology
- Personalized Medicine
- Wearables
- Particle Separation
- Drug Delivery
- Chemical Screening
- Cell Culture
- In Vitro Testing
- Synthesis
- Soft Robotics/Haptics
- Nucleic Acid Sample/Library Prep.
- Reaction Optimization





Automated Cell Sorting


Haptic Feedback Glove – Meta



Microreactor

Automated Nucleic Acid Sample Preparation

Nucleic acid sample and library preparation is a time consuming and complex task. Current systems like the mercury lab provide on-site DNA analysis, however, they require skilled users and the use of several systems from sample to answer. We are currently working on developing an automated sample to answer system that would reduce user interaction and open up DNA analysis to a wider clientele.

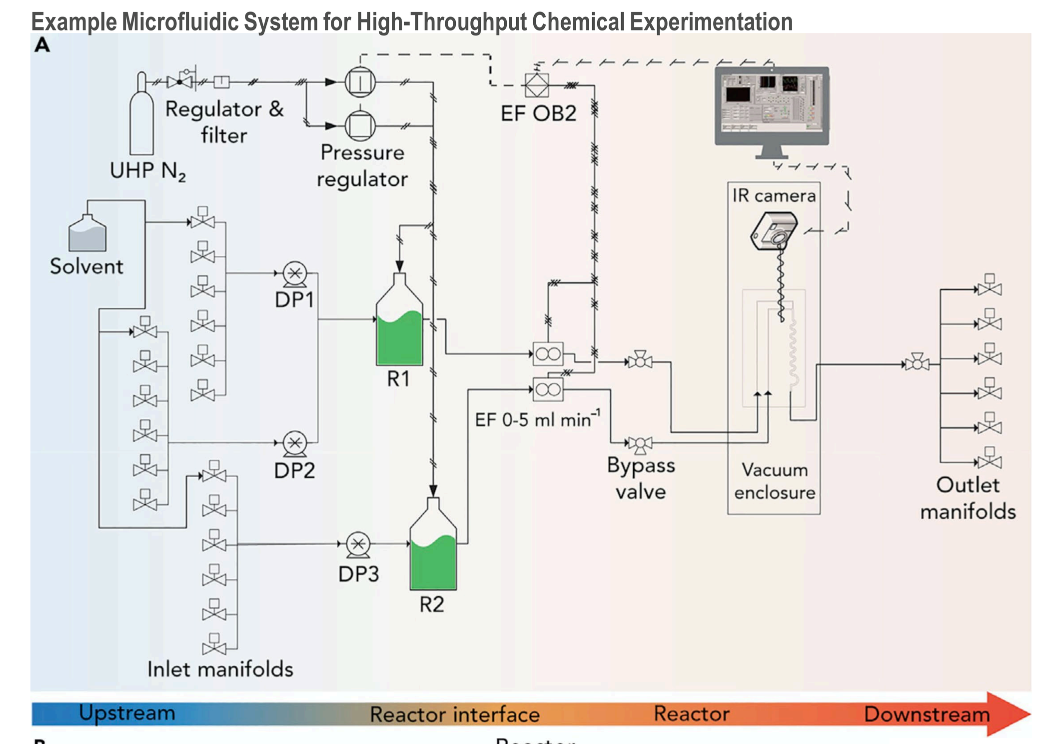
Automated Nucleic Acid Preparation System: QIASymphony by QIAgen

Digital Microfluidic Library Preparation: Voltrax by Oxford Nanopore

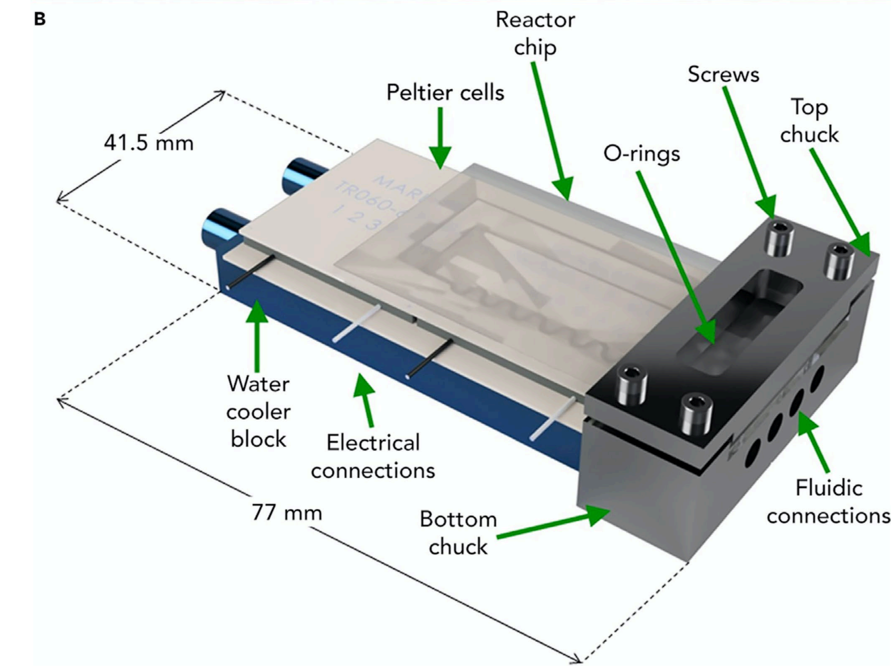
AI Supported Reaction Optimization

The synthesis group currently uses expensive catalysts in large batch reactions. This method is time consuming and expensive to optimize. Microfluidics can reduce the amount of reagent used for reaction optimization and be controlled by AI for hands off optimization. An example system is shown

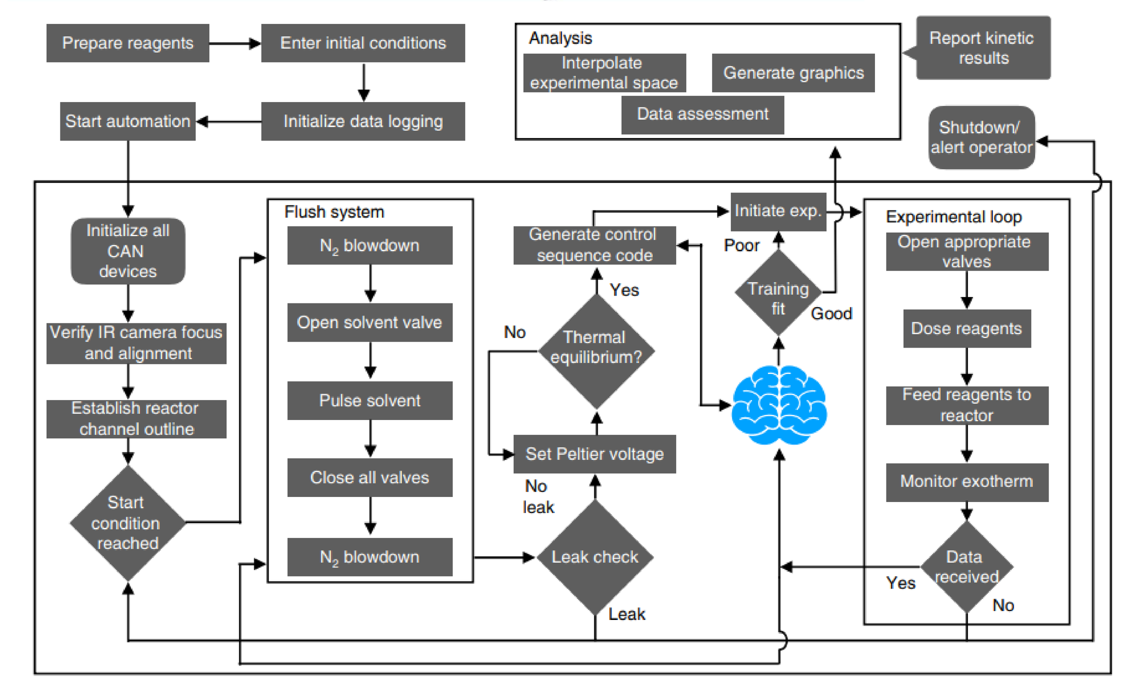
Example Microfluidic System for High-Throughput Chemical Experimentation



(A) Process flow diagram of an automated thermographic microreactor. Left to right: inlet manifolds with solvent tank, ultra-high purity (UHP) nitrogen supply, electromagnetic dosing pumps (DP), reagent reservoirs (R), pressure controller (EF OB2), mass flow meters (EF), bypass valves, infrared (IR) camera, vacuum enclosure, and outlet manifold.



(B) Computer-aided design of a microfluidic chip for the study of metallocene catalysts. The device includes a reactor, fluid interface connections, Peltier cells for heating/cooling, and a liquid cooling block for thermal stability.



(C) Flowchart of how experiments are performed, from reagent preparation to a report of the kinetic results. Analysis was performed after the experimental sequence was complete. CAN, controller area network; UI, user interface.

Source: Rizkin, B.A., Shkolnik, A.S., Ferraro, N.J. *et al.* Combining automated microfluidic experimentation with machine learning for efficient polymerization design. *Nat Mach Intell* **2**, 200–209 (2020).

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